

how this reference of the whole phænomenon to endosmose leaves totally unexplained a series of such phænomena as the swelling up of a particular region of cells in consequence of irritation in sensitive plants. It may be also from the influence of the phænomenon in question, that in many plants the primordial utricle separates from the cell-wall in the dead plant, and in this way the cell-sap comes into direct contact with the cell-wall. However, it appears to me, as I have already remarked, that it is rash at present to talk either about this or other possibilities, since facts, on which a solid theory can be built, time has yet to furnish us with.

IX.—*On the relative Duration of the Power to germinate, in Seeds belonging to different Families.* By M. ALPH. DECANDOLLE*.

(*First experiment.*)

THE relative permanence of the faculty of germination in different species of seeds has never been examined with the precision that the present condition of science demands. The "practice" of gardens has taught in a vague and superficial manner, that certain seeds soon lose their power of germination, others but slowly; that the collecting of seeds, the manner in which they are preserved, transported, and lastly, sown, influence greatly the result of the sowings. It is well known that by a suitable degree of humidity and heat, may be obtained the germination of seeds which otherwise would remain inert or be spoilt. Facts of this kind have resulted from the observation of every horticulturist, and it would be useless to seek to contest them, because the conditions of the sowings vary and are scarcely ever comparative. On the other hand, physiologists have directed attention in their works to the germination of some very old seeds†, but these are isolated cases, perhaps exceptional, and which cannot be compared with each other, since the seeds have been submitted to different conditions.

It appeared to me to be of some interest to ascertain the faculty of germination, after a given lapse of time, in seeds, belonging to different families, but collected simultaneously in the same garden, transported and preserved in the same manner, finally, sown in equal number in similar conditions of soil, humidity and temperature. Well-observed physiological facts have

* From the *Ann. des Sc. Nat.*, Dec. 1846. Translated by Arthur Henfrey, F.L.S. &c.

† DeC. *Physiol. Végét.* p. 618 *et seq.* Desmoulins, Documents relatifs à la faculté germinative conservée par quelques graines antiques. Pamphlet in 8vo. Ed. 2. July 1846.

always value in themselves. I foresee moreover, in the present case, certain applications to geographical botany. Thus the duration of the faculty of germination, be it absolute or relative, may have an influence on the frequency of the individuals of each species, on their appearance in new localities the nature of which has changed, and, when the seeds have been deposited a long time, on the effect of transportation from one country to another, and in general on the geographical extension of species.

The idea of ascertaining facts of this kind occurred to me in 1832, when I made the observations which are contained in the 'Physiologie Botanique' of my father*, on the relative rapidity with which germination takes place in the different families of plants. I then preserved packets of seeds in order to sow them after a certain number of years, and as in the summer of 1846, the students who were attending the higher course of botany showed themselves disposed to aid me in some researches or experiments, I recollected my store of old seeds and arranged to sow them at once.

The principal collection which I chose for the experiment had been sent in 1832 from the Botanical Garden at Florence. The seeds had therefore been collected in 1831, and when I sowed them on the 14th of May 1846, they were all nearly fifteen years old. During this long space of time they had been preserved in a dark cabinet, out of the influence of humidity or extreme variations of temperature. There were several hundreds of them, but I was satisfied with taking, at random, 368 species belonging to a large number of different genera and families. That the comparison might be exact, it was necessary to sow an equal number of the seeds of each species. I fixed upon the number 20. It was a long and tedious operation to pick and count them, throwing away such as appeared spoilt. In most instances it was necessary to use a lens. Seeing how many thousands of seeds were included in the sowing of certain species, I could not help thinking that the small seeds germinate less frequently than the large, and I suspected that the contrary opinion held by gardeners resulted from the enormous inequality of the number in the sowings of small and large seeds. The result of our experiment should confirm one or other of these two opinions. The seeds were sown in pots, in peat mould, in order to avoid weeds, of which in fact there were but a very small number. The seeds were watered from time to time. The mean temperature of the month of June, the period when several species sprung up, was 19° Centig. (about 66° Fahr.); that of July 18°·5 Cent., according to observations at nine in the morning and nine at night, pub-

* *Physiol. Bot.* p. 639 *et seq.*

lished in the 'Bibliothèque Universelle de Genève.' The maximum several times reached 30° and even 31° Cent. (about 86° Fahr.). The pots were kept under examination till the autumn, but scarcely any seeds sprung up after the end of June.

The following are the species submitted to experiment. Those which did not come up are in the ordinary type; those of which a few came up, the number being less than half the twenty seeds sown, are in italics; lastly, the single species of which more than half came up, is in small capitals:—

<i>Asclepiadeæ.</i>	<i>Silene antirrhina.</i>
<i>Asclepias amœna.</i>	<i>noctiflora.</i>
<i>Amyrideæ.</i>	<i>Lychnis Githago.</i>
<i>Amyris polygama.</i>	<i>Gypsophila scorzonæræfolia.</i>
<i>Amaranthaceæ.</i>	<i>Arenaria marina.</i>
<i>Amaranthus prostratus.</i>	<i>media.</i>
<i>caudatus.</i>	<i>Gypsophila vaccaria.</i>
<i>giganteus.</i>	<i>Chenopodeæ.</i>
<i>cernuus.</i>	<i>Atriplex tatarica.</i>
<i>paniculatus.</i>	<i>rosea.</i>
<i>curvifolius.</i>	<i>hortensis.</i>
<i>speciosus.</i>	<i>Basella alba.</i>
<i>Celosia argentea.</i>	<i>Blitum virgatum.</i>
<i>cristata.</i>	<i>Beta maritima.</i>
<i>Balsamineæ.</i>	<i>Chenopodium maritimum.</i>
<i>Impatiens Balsamina, fl. pl.</i>	<i>Emex spinosus.</i>
<i>Boragineæ.</i>	<i>Cistineæ.</i>
<i>Echinosperrum Lappula.</i>	<i>Cistus villosus.</i>
<i>Lithospermum officinale.</i>	<i>monspeliensis.</i>
<i>Asperugo procumbens.</i>	<i>Helianthemum salicifolium.</i>
<i>Anchusa ovata.</i>	<i>Compositæ.</i>
<i>Campanulaceæ.</i>	<i>Gnaphalium sylvaticum.</i>
<i>Campanula sibirica.</i>	<i>Crepis aspera.</i>
<i>pyramidalis.</i>	<i>Parthenium hysterophorum.</i>
<i>medium.</i>	<i>Geropogon australis.</i>
<i>Capparideæ.</i>	<i>Onopordon illyricum.</i>
<i>Cleome viscosa.</i>	<i>Calendula suffruticosa.</i>
<i>triphylla.</i>	<i>Melananthera deltoidea.</i>
<i>Caryophylleæ.</i>	<i>Artemisia vallesiaca.</i>
<i>Silene apetala.</i>	<i>Pyrethrum corymbosum.</i>
<i>conoidea.</i>	<i>Flaveria contrayerva.</i>
<i>gallica.</i>	<i>Chrysanthemum coronarium.</i>
<i>cerastioides.</i>	<i>Centaurea atropurpurea.</i>
<i>vespertina.</i>	<i>Artemisia annua.</i>
<i>fruticosa.</i>	<i>Barkhausia graveolens.</i>
<i>quinquevulnera.</i>	<i>Artemisia Abrotanum.</i>
<i>conica.</i>	<i>Pyrethrum daucifolium.</i>
<i>tricuspidata.</i>	<i>Zinnia multiflora fl. luteo.</i>
	<i>Artemisia camphorata.</i>
	<i>Verbesina serrata.</i>
	<i>Eclipta erecta.</i>
	<i>Bœbera chrysanthemoides.</i>
	<i>Flaveria repanda.</i>

Cirsium eriophorum.
 Eupatorium cannabinum.
 Elephantopus scaber.
 Onopordon tauricum.
 Madia sativa viscosa.
 Serratula alata.
 Cacalia sonchifolia.
 Calendula pluvialis.
 Centaurea dealbata.
 Silphium trifoliatum.
 Pyrethrum tenuifolium.
 Centaurea sempervirens.
 Helianthus pubescens.
 Urospermum Dalechampii.
 Stevia ovata.
 Osteospermum cæruleum.
 Ampherephus aristata.
 Conyza ivæfolia.
 Helianthus annuus.
 Calendula officinalis.
 Bidens cernua.
 Eupatorium sessilifolium.
 Picris hieracioides.

Coniferae.

Cupressus pyramidalis.

Convolvulaceæ.

Convolvulus sepium.

Cruciferae.

Camelina sativa.
 Brassica incana.
 Sisymbrium persicum.
 Alyssum micropetalum.
 Iberis pinnata crenata.
 Brassica Eruca.
 Matthiola incana.
 Barbarea vulgaris.
 Erysimum perfoliatum.
 Camelina dentata.
 Neslia paniculata.
 Arabis sagittata.
 Lunaria biennis.
 Alyssum rostratum.
 saxatile.
 Matthiola annua.
 Sinapis nigra torulosa.
 Thlaspi alpestre.
 Sisymbrium hirsutum.
 Sinapis alba flexuosa.
 Malcolmia maritima.
 Sinapis dissecta.
 Thlaspi perfoliatum.
 Erysimum strictum.
 Crambe hispanica.
 Nasturtium indicum.
 Biscutella Apula.

Brassica Napus.
 Cochlearia glastifolia.
 Bunias orientalis.
 Erysimum cuspidatum.
 Thlaspi arvense.
 Arabis auriculata.
 Sisymbrium acutangulum.

Cucurbitaceæ.

Cucumis serotinus.
 Dudaim.

Dipsaceæ.

Succisa rigida.
 Dipsacus Fullonum.
 Succisa pratensis.

Euphorbiaceæ.

Euphorbia chamæsycea.
 terracina.
 hypericifolia.
 Phyllanthus Niruri.

Frankeniaceæ.

Frankenia pulverulenta.

Gentianaceæ.

Gentiana asclepiadea.

Geraniaceæ.

Erodium pimpinelloides.
 pulverulentum.
 melanostigma.

Gramineæ.

Bromus racemosus.
 stenophyllus.
 Lappago racemosa.
 Andropogon laguroides.
 Phalaris bulbosa.
 canariensis.
 paradoxa.
 Panicum miliaceum nigrum.
 erucæforme.
 avenaceum.
 miliaceum album.
 capillare.
 Setaria scrobiculata.
 italica.
 macrostachya.
 macrochaeta.
 Saccharum strictum.
 Poa littoralis.
 pilosa.
 verticillata.
 Festuca delicatula.
 Agrostis monandra.
 Hordeum nepalense.

Oryza latifolia.
Paspalum scrobiculatum.
Lolium tenue.
 temulentum.
Digitaria humifusa.
 ciliaris.
Triticum imbricatum.
Oryza sativa monstrosa.
Eleusine coracana.

Hydrophyllaceæ.

Ellisia nyctelæa.

Hypericineæ.

Hypericum elatum.
 perforatum.

Irideæ.

Iris dichotoma.
 Xiphium.
Tigridia Pavonia.
Ixia ramiflora.
Trichonema neglecta.

Labiataæ.

Salvia lanceolata.
 Æthiopis.
 tingitana.
 verticillata.
 viscosa.
 indica.
 hispanica.
 sclarea.
 verticillata napiifolia.
 hirsuta.

Ocimum basilicum.
Stachys annua.
Ajuga pyramidalis.
Leucas martinicensis.
Satureia hortensis.
Nepeta lanceolata.
Nepeta botryoides.
Ocimum basilicum maxim.
 minimum nigrum.
Galeopsis versicolor.
Teucrium hircanicum.
 orientale.

Plectranthus fruticosus.
 scutellerioides.
 parvifolius.

Lumnitzera tenuiflora.
Hyssopus officinalis.
Lavandula multifida.
Hyptis radiata.
Marrubium astrakanicum.

Leguminosæ.

Dolichos abyssinicus.

Dolichos niloticus.
Vicia biflora.
Vicia sordida.
DOLICHOS UNGUICULATUS.

Dolichos brasiliensis.

Coronilla valentina.

Trifolium spumosum.

Trifolium expansum.

Trifolium Gussoni.
 melacanthum.
 reflexum.
 aristatum.

Trifolium subterraneum.

Trifolium pratense.
 alexandrinum.
 rubens.
 arvense.
 maritimum.

Acacia farnesiana.
 glandulosa.

Lathyrus cicera.

Amorpha fruticosa.

Melilotus cretica.
 officinalis.
 messaniensis.
 officinalis fl. albo.
 cæruleus.

Medicago denticulata.

Ervum longifolium.

Ervilia.

tetraspermum.

Coronilla Emerus.
 junceæ.

Cytisus laburnum.

Baptisia australis.

Lablab vulgaris sem. nigro.

Anthyllis vulneraria.

Sesbania aculeata.

Mimosa Julibrissin.

Ononis hispida.

Phaseolus Cafer.

Phaca alpina.

Trigonella spinosa.

Lotus Jacobæus.

Liliaceæ.

Allium sphærocephalum.
 cepa, ægyptiacum.
 gracile.

Lineæ.

Linum usitatissimum humile.

Lythrarieæ.

Ammania latifolia.
Cuphæa viscosissima.
Ammania diffusa.

Malvaceæ.

Malva *limensis.*
Malva *caroliniana.*
lactea.
Lavatera *arborea.*
cretica.
Urena *lobata.*
Kitaibelia *vitifolia.*
Sida *hastata.*
mollissima.
Æthæa *narbonensis.*

Myrtaceæ.

Psidium *aromaticum.*

Onagrariceæ.

Œnothera *biennis.*
Epilobium *hirsutum.*
Œnothera *sinuata.*
mutabilis.

Papaveraceæ.

Papaver *Argemone.*
Rhæas.
hybridum.
orientale.
Argemone *mexicana* *alba.*
Chelidonium *majus.*

Paronychieæ.

Corrigiola *littoralis.*
Herniaria *vulgaris.*
Mollia *diffusa.*

Phytolacceæ.

Phytolacca *decandra.*
Rivina *brasiliensis.*

Plantagineæ.

Plantago *lanceolata.*
maxima.
vaginata.
Cynops.
media.

Plumbagineæ.

Statice *spatulata.*

Polygoneæ.

Polygonum *orientale.*
tataricum.
Rumex *Lunaria.*
Hydrolapathum.
littoralis.

Portulacaceæ.

Portulaca *pilosa.*

Primulaceæ.

Cyclamen *persicum.*
Anagallis *carnea.*
latifolia.
Lysimachia *vulgaris.*
Androsace *maxima.*

Ranunculaceæ.

Nigella *Damascena* *fl. pl.*
Thalictrum *aquilegifolium.*
flavum.
densiflorum.
Ranunculus *parviflorus.*
muricatus.
bulbosus.
Aquilegia *canadensis.*
Nigella *Damascena.*

Resedaceæ.

Reseda *odorata.*

Rhamneæ.

Rhus *lucidus.*
Ceanothus *americanus.*

Rosaceæ.

Sanguisorba *canadensis.*

Rubiaceæ.

Bigelowia *verticillata.*
Asperula *arvensis.*
cynanchica.
Crucianella *latifolia.*
Galium *spurium.*
Spermacoce *rubra.*

Sapindaceæ.

Cardiospermum *Corindum.*

Scrophulariaceæ.

Bartsia *Odontites.*
Verbascum *phlomoides.*
Blattaria.
Thapsus.
floccosum.
Digitalis *orientalis.*
lanata.
intermedia.
purpurea.
Scrophularia *aquatica.*

Solanaceæ.

Nicotiana *glutinosa.*
rustica, asiatica.
Solanum *Zuccagnianum.*
ciliatum.
tomentosum.
Datura *Tatula.*
Hyoscyamus *Senecionis.*

Tiliaceæ.

Corchorus olitorius.
Triumfetta trilclada.

Umbelliferæ.

Ligusticum apioides.
Hasselquistia cordata.
Bupleurum semicompositum.
Cenanthe Phellandrium.
Bupleurum junceum.
Anthriscus vulgaris.
Selinum lineare.
Conium maculatum.
Biforis flosculosa.
Eryngium asperum.

Urticaceæ.

Datisca cannabina.
Urtica pilulifera.

Valerianææ.

Centranthus ruber.

Verbenaceæ.

Lantana involucrata.
Verbena urticæfolia.
 officinalis.
Priva mexicana.
Vitex Agnus-castus.
Stachytarpheta angustifolia.
 aristata.
Lippia rubra.

One is struck, at the first glance, at the very small number of species which germinated. By counting, we find seventeen out of 386. Moreover the germinative power was much weakened in those which did come up. In fact, out of the seventeen species which came up, *Dolichos unguiculatus* is the only one that yielded more than half the seeds sown (fifteen out of twenty). The others had, for the most part, one, two or three germinations in twenty seeds. *Lavatera cretica* approached nearest to *Dolichos*, but there were only six seeds which germinated out of twenty.

The different natural families may be classed as follows; commencing with those where the largest proportion of species preserved the power of germinating, and ending with those where, more than ten species having been sown, none came up.

Malvaceæ, of which came up 5 out of 10 species sown, or 0.50					
Leguminosæ, ———	9	—	45	———	0.20
Labiataæ, ———	1	—	30	———	0.03
Scrophulariaceæ, ———	0	—	10	———	0.00
Umbelliferæ, ———	0	—	10	———	0.00
Caryophyllaceæ, ———	0	—	16	———	0.00
Graminaceæ, ———	0	—	32	———	0.00
Cruciferæ, ———	0	—	34	———	0.00
Compositæ, ———	0	—	45	———	0.00

No conclusion can be drawn from the fact, that none came up out of nine *Amaranthaceæ*, nine *Ranunculaceæ*, eight *Chenopodiaceæ*, eight *Verbenaceæ*, seven *Solanaceæ*, six *Papaveraceæ*, six *Rubiaceæ*, &c., nor from that, for example, the single *Balsaminaceous* plant sown came up, for the numbers are too small, and the result perhaps depends on the selection of the seeds sown representing these families. That which comes out in a very evident manner is the superiority of the *Malvaceæ* and *Leguminosæ* as to the duration of the faculty of germination, and the inferiority of the *Compositæ*, *Cruciferæ* and *Graminaceæ*.

In this comparison of the families, we are obliged to leave on one side a large number of species. This is not the case when

we compare the annual, biennial, perennial and ligneous plants. There were in the experiment 357 species, the duration of which is known from botanical books, and 11 of which this is doubtful, either in itself or on account of some doubt as to the specific name. The 357 species which may be taken into account class themselves thus:—

Species.	Total number.	Number of those which came up.	Out of 100 species came up.
Annals.....	180	9	5.0
Biennials	28	0	0.0
Perennials	105	4	3.8
Ligneous	44	3	6.7
Total.....	357	16	4.4

Or,

Monocarpons.....	208	9	4.3
Polycarpons	149	7	4.7
Total.....	357	16	4.4

These figures seem to prove that the woody species preserve the power to germinate longer than the others, while the biennials would be at the opposite extreme. However, we must observe the small number of species in these two categories, from which it will be concluded that with regard to them the experiment was insufficient. As to the perennial plants compared with the annuals, it seems probable that their faculty of germination is lost rather more quickly.

Do the large seeds preserve the faculty of germination better than the small ones? Our experiment can answer this question but imperfectly. In fact, we did not sow *very large* seeds, like those of the Cocoa for instance; nor even *large* seeds, like those of many Palms, certain Leguminosæ, Sapotacæ or Coniferæ. The seeds in the collection were of a *mean* size, like the Haricots, the seeds of Iris, of Convolvulacæ, &c.; or *small* seeds, like those of Compositæ, Graminacæ, Geraniacæ, &c.; or lastly, *very small* seeds, such as those of the Poppies, Plantago, Amaranthacæ, &c. It would be difficult to class all the seeds sown in the different degrees of magnitude; only we may remark among the species which came up a rather large proportion of the *mean* or *small* (Dolichos, Malvacæ, Balsam, Acacia, Vicia), while the *very small* seeds did not come up. We have thus a confirmation of the idea conceived at the time of sowing, namely, that the reproduction of the species with very small seeds is assured by their number rather than by the duration of the germinative power. This is not surprising, since the very small seeds have a much larger surface in proportion to their volume, and are consequently more readily penetrated by the variations of temperature or humidity which affect the organs. It is probable also that a much larger proportion of the very small seeds

are sterile. This our experience does not allow of our stating as ascertained; but we are led to presume it by the difficulty of getting to germinate the fresh seeds of the Orchidaceæ, the Orobanchaceæ, and some other families with extremely small seeds.

The Leguminosæ and Malvaceæ, which preserve the germinative faculty so well, are seeds possessing little or no albumen, especially the Leguminosæ; but the Cruciferæ and the Compositæ, which are at the opposite extreme, have still less than they. The Graminaceæ and Umbelliferæ, which have large albumens, did not preserve their powers. Thus the circumstance of the presence or the absence of albumen appears in general indifferent; although doubtless certain albumens, like those of the Coffees, the Umbelliferæ, &c., are bad to preserve on account of special chemical conditions. In other points of view, the structure of the seed and fruit appears equally unimportant. It might perhaps have been thought, for example, that the seeds of the Compositæ, being covered by the pericarp and the calyx, would be better preserved than others. Experience has shown, on the contrary, that they lose their vital powers in the highest degree.

Finally, there is some interest in comparing the present experiment with those which I made in 1832, on the relative rapidity of germination in the different families*; it will there be seen that the Amaranthaceæ, the Cruciferæ, the Caryophyllaceæ, which germinate very quickly, lose their power of germination in a few years; that the Malvaceæ germinate rapidly, and lose their properties slowly; that the Leguminosæ, on the contrary, germinate slowly enough, and lose their power still more slowly; lastly, that the Umbelliferæ and Scrophulariaceæ germinate slowly, and lose their vitality in a few years. It appears, from these results, that the duration of the faculty of germination is most frequently in an inverse proportion to the power of germinating quickly, though without doubt there are numerous exceptions. Thus the very small seeds, which are seen to germinate quickly, are also affected sooner; while the seeds rather larger or of a mean size germinate slowly or endure long.

Such are the conclusions which result from this first experiment. They show the necessity of others, in order to compare a greater number of families and to verify certain probable speculations. The seeds which I have kept in reserve allow me to return to the subject. In the meantime, as these observations have been made with all suitable precautions, and as they form, with my experiments of 1832 and with those which I project, a general examination of germination considered in a physiological point of view, it seemed to me that it would be of use to publish them.

* *Physiol. Végét.* p. 648.